CHAPTER FIVE

Identification of the Type and Quality of Gloucester Harbor Coastal and Seafloor Habitats: Synthesis of Harbor and Regional Studies

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Abstract

This study synthesized the results of statewide coastal habitat and seagrass mapping, regional seafloor habitat mapping and harbor-specific seafloor habitat assessments for Gloucester Harbor. Five coastal habitats, several eelgrass beds and four seafloor habitats with variable features were found within Gloucester Harbor. Human-induced disturbance was apparent along a gradient from degraded seafloor conditions in the Inner Harbor to non-degraded, higher seafloor quality in the Outer Harbor. The study used sediment profile imaging, a multibeam seafloor mapping system and diving observation to identify, describe and map seafloor habitats. The utility of each method was discussed. The different methodologies and data collected emphasized the importance of using multiple techniques to thoroughly assess seafloor habitat conditions. The integration of results provided the first assessment of Gloucester Harbor coastal and seafloor resources. The study discusses the value of marine habitat mapping and monitoring.

Introduction

Comprehensive coastal and seafloor habitat maps are fundamental to understanding and appropriately managing marine habitat and life. The Massachusetts Department of Environmental Protection (DEP) produced maps showing the statewide distribution of coastal habitats, such as salt marsh, rocky intertidal, and tidal flats, and seagrass. The DEP maps provide essential information that increase the understanding of statewide coastal and seagrass resources and improve management of these resources. No single program systematically examines or maps seafloor habitats in Massachusetts.

The lack of seafloor habitat characterization and maps hinders resource management efforts. Seafloor habitat conditions influence the presence, absence, and productivity of demersal creatures, including exploited and non-target species. Seafloor environments, including benthic habitats and inhabitants, found in coastal Massachusetts support a relatively diverse assemblage of species and life history stages. Threats to seafloor and coastal habitat occur from a range of human activities, including fishing, pollution, dredging and dredged material disposal, aquaculture, construction of structures, and shipping. Impacts from threats are frequently ignored and difficult to quantify without habitat mapping and monitoring. Mapping and monitoring of coastal and seafloor habitats are required to detect long-term change in habitat quality, benthic community structure, and ecological processes (e.g., trophic dynamics).

Gloucester Harbor (Figure 5.1) was investigated by a series of surveys to characterize fisheries resources and benthic habitats (MCZM 2001). The surveys were not intended to comprehensively describe seafloor habitat; however, substantial geographic areas of the seafloor environment were investigated, analyzed, and described. Existing statewide and regional assessments provided baseline conditions and complimentary information on coastal habitats, sea-

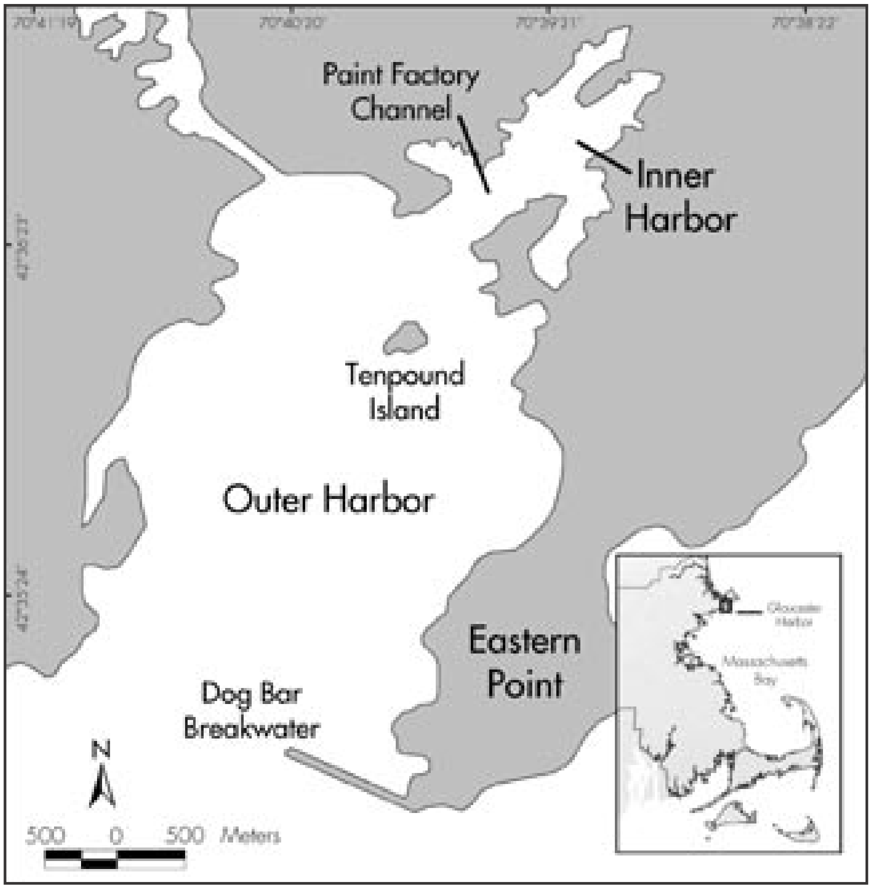

FIGURE 5.1 Landmarks and geographic features in Gloucester Harbor.

grass, and seafloor resources. This study synthesizes harbor-specific and regional research to identify and describe coastal and seafloor habitat types and conditions in Gloucester Harbor. The study discusses the significance and management application of mapping and monitoring seafloor habitat.

Coastal Habitats

Methods

The Massachusetts DEP mapped the statewide distribution of wetlands and streams, including coastal habitats. Habitats were interpreted from stereo, 1: 12000 scale, color-infrared photography and 1:5000 black and white ortho-rectified digital aerial photography (MassGIS 2002). Remotely sensed maps were extensively field verified, and maps were generated at 1:5000 scale. The DEP maps identify coastal and terrestrial features. This study presents the distribution of coastal habitats in Gloucester Harbor.

Results and Discussion

Coastal beach, sea cliff (bank bluff), salt marsh, rocky intertidal, and tidal flats line the outer harbor of Gloucester (Figure 5.2). The western shore is more exposed to the open ocean, characterized by rocky intertidal and sea cliffs. There are limited areas of salt marsh and pockets of coastal beach throughout the outer harbor. The outer harbor coastline was altered by the construction of Dog Bar breakwater, but the majority of the coastal habitats persisted through the development of Gloucester. The inner harbor was drastically changed through the development of the harbor. The inner harbor was extensively filled (e.g., harbor waters were filled to and around Fivepound Island to create the State Pier) and was heavily armored with man-made structures. Patches of sea cliff, coastal beach, tidal flats and salt marsh remain in the inner harbor (Figure 5.2).

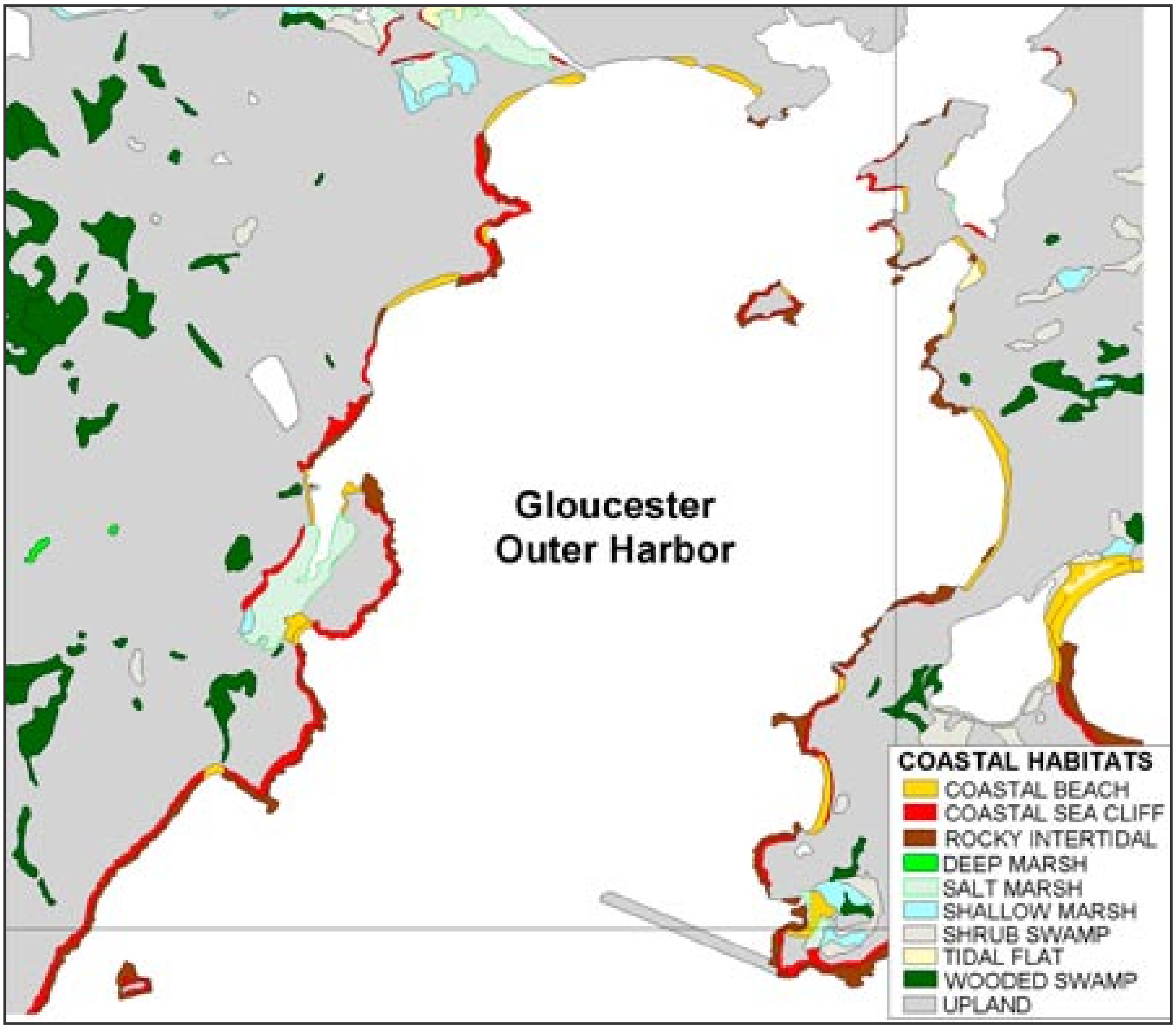

FIGURE 5.2 Coastal habitats in Gloucester Harbor (MassGIS 2002).

Submerged Vegetation

Methods

Eelgrass (*Zostera marina*) and widgeon grass (*Ruppia maritima*) are two species of submerged rooted vegetation (SRV) found in Massachusetts marine and estuarine waters. Eelgrass is the dominant species in Massachusetts. DEP (Costello personal communication) mapped the statewide distribution of seagrass through aerial photography (at a scale of 1:20000), photographic interpretation, and extensive field verification. Data presented in this study are from the 1995 assessment.

Results and Discussion

Eelgrass is a productive nearshore marine habitat that supports diverse floral and faunal assemblages, absorbs nutrients, stabilizes sediments, and provides detrital biomass for lower trophic levels (see Stephan and Bigford 1997 and Fonseca et al. 1998 for review). Wasting disease (*Labyrinthula* spp.) decimated North Atlantic eelgrass populations during the early 1930s, including populations in Gloucester Harbor. The loss of eelgrass substantially affected wildlife resources (e.g., avifauna foraging habitat) (Addy and Aylward 1944; Dexter 1985). Eelgrass populations recovered in Gloucester Harbor and Cape Ann waters (Addy and Aylward 1944; Dexter 1985), and distribution has remained stable (Buchsbaum personal communication). The 1995 DEP survey showed that Gloucester Harbor contained five discrete eelgrass beds in the outer harbor (Figure 5.3).

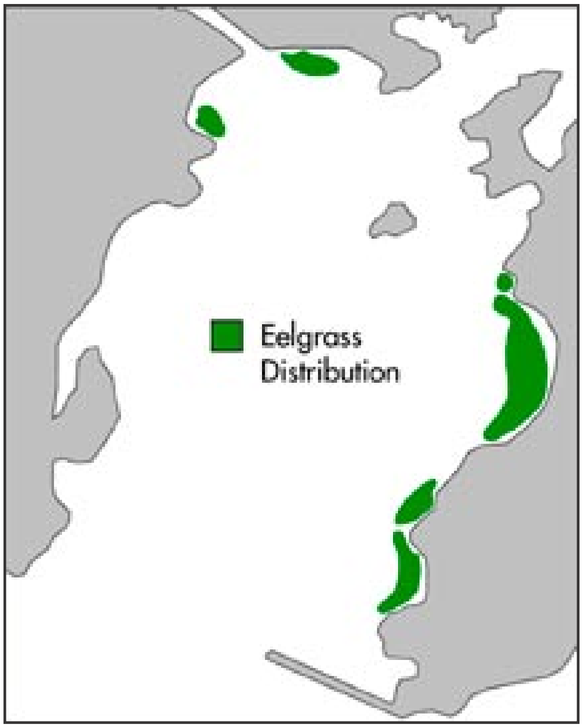

FIGURE 5.3 Distribution of eelgrass (*Zostera marina*) in Gloucester Harbor (eelgrass map produced from 1995 aerial photography and field verification; C. Costello personal communication; www.state.ma.us/mgis/massgis.htm).

These results are based on one sample but indicate suitable environmental conditions to support eelgrass habitat in Gloucester Harbor. The distribution and quality of eelgrass is temporally and spatially variable, and there is no long-term record of seagrass distribution in Gloucester Harbor. Trends of seagrass distribution and quality cannot be determined with the existing information. Previous studies (1930-1984) demonstrated the variability of eelgrass distribution around Cape Ann (Dexter 1985), but sampling within Gloucester Harbor during this period was limited (Addy and Aylward 1944). Eelgrass distribution is influenced by a combination of natural and anthropogenic factors, including proliferation of epiphytic growth and disease, pollution, direct disturbance, physical alteration to the watershed, and natural cycles (NOAA 1997). Relationships between seagrass quality and human-influences are not fully understood (e.g., Lent et al. 1998). It is assumed that harbor water quality improved with the movement of the wastewater outfall from the outer harbor to south of the Dog Bar Breakwater. Excessive nutrients were not observed in the outer harbor (Michael and Fleming 2000), and nitrogen loading does not appear to reduce eelgrass quality in Gloucester Harbor (Chandler et al. 1996; Lent et al. 1998). Recent aerial photography (2001) provided a complimentary dataset that indicated no loss of eelgrass coverage in Gloucester Harbor from 1995 to 2001 (Costello personal communication).

Seafloor Habitat

Methods

Science Applications International Corporation (SAIC) collected and analyzed sediment surface and sediment profile images to describe benthic habitat type and quality (Valente et al. 1999; SAIC 2001). Rhoads and Germano (1982; 1986) describe sediment profile imagery methodology and analyses. Photographs of the sediment surface were obtained with a downward-looking camera; the resultant surface images show a 40 cm by 60 cm area of the seafloor. The surface images provide an undisturbed record of seafloor features (i.e., sediment type, topography, and biogenic structures). Sediment profile images (SPI) were collected with a specialized camera that penetrates into the seafloor and obtains a vertical cross-section photograph (profile) of the upper 15 to 20 cm of the seafloor, including the sediment-water interface. The seafloor was photographed with the Benthos Model 3731 Camera (Benthos Inc, Falmouth, MA). Underwater color photographs were digitized, and an image analysis system was employed to analyze SPI (Valente et al. 1999).

Features identified by SPI include sediment type, grain size, camera penetration, apparent redox potential discontinuity (RPD) depth, biogenic structure (worm tubes) and activity (burrows and feeding voids), and benthic habitat type (Rhoads and Germano 1982, 1986; Nilsson and Rosenberg 1997). The Wentworth classification scheme was used to describe sediment grain size in this study (see Table 5.1 for equivalent metric units). Seafloor rigidity (i.e., surface sediment hardness or bearing strength) was measured by camera penetration. RPD depth is an estimate (apparent) of oxidation of surficial sediments. The RPD depth estimate is the distance between high-reflectance surface sediment (oxic sediments) and low-reflectance sediment (anoxic sediment).

TABLE 5.1 Sediment profile imaging data, including grain size major mode frequency, camera penetration, apparent RPD depth, and habitat type, from 1998 and 2001 (Valente et al. 1999; SAIC 2001). NA represents SPI samples that did not penetrate the seafloor (hard bottom). Means (SD) included where relevant.

Substrate	All 1998	Inner Harbor 1998	Paint Factory Channel 1998	Tenpound Island 1998	Tenpound Island 2001	Outer Harbor 2001	All 2001
Frequency of Grain Size (phi) Mode[a]							
>4	90.9	94.1	66.7	100.0	100.0	73.1	76.6
4 to 3	6.1	5.9	16.7			23.9	20.8
<-1	3.0		16.7				
NA						3.0	2.6
Camera Penetration (cm) Mean	14.0 (4.8)	13.6 (4.6)	12.5 (7.5)	15.4 (2.9)	15.5 (3.1)	10.7 (5.0)	11.3 (5.0)
Apparent RPD Depth (cm) Mean	4.9 (2.6)	3.5 (2.4)	5.8 (2.7)	6.9 (1.3)	10.8 (4.1)	6.0 (4.0)	6.6 (4.3)
Habitat Type	mix	soft mud (silt)	soft mud (silt); hard bottom	soft mud (silt)	soft mud (silt)	soft mud (silt); sand; hard bottom	mix

[a]**Grain Size:** >4 phi = <0.0625 mm; 4 to 3 phi = 0.625 - 0.125 mm; 3 to 2 phi = 0.125 - 0.250 mm; 2 to 1 phi = 0.250 - 0.50 mm; 1 to 0 phi = 0.50 - 1.00mm; 0 to -1 phi = 1.00 - 2.00 mm; <-1 phi = >2.00 mm

Sediment profile images were collected throughout Gloucester Harbor in 1998 and 2001 (Valente et al. 1999; SAIC 2001). Sediment surface images were concurrently collected with the 1998 SPI. The benthos from the inner harbor to Tenpound Island were sampled in 1998 and included 33 SPI and 22 surface images. Seventy-seven SPI were collected from Tenpound Island to Dog Bar Breakwater in 2001. Tenpound Island stations were sampled in 1998 and 2001. Four of the 2001 stations targeted the historic location of the wastewater outfall (located in the outer harbor).

This paper incorporated an existing regional study (USGS 1998) and site-specific surveys (NAI 1999; Malkoski personal communication). USGS employed a multibeam seafloor mapping system that used sound to measure water depth (i.e., bathymetry) and surficial sediment characteristics (USGS 1998). The mapping system also included the collection of sidescan sonar data. The survey provided a highly detailed map (scale of 1:25000) of seafloor topography and substrate type for portions of Gloucester Harbor, Massachusetts Bay, Jeffreys Ledge, and Stellwagen Bank.

Diving surveys, during October 1999 and January 2001, targeted areas in the inner and outer harbor (Figure 5.4; NAI 1999; Malkoski personal communication). NAI (1999) assessed 10 metered transects of varying length from the inner harbor to Tenpound Island, totaling 3450 linear meters (NAI 1999). The winter survey contained four 200 meter transects (Malkoski personal communication). Divers swam the length of each transect and recorded substrate type, number of lobster, and presence of additional biogenic features (e.g., fish, invertebrates, and vegetation), providing a qualitative and quantitative assessment of seafloor features. Underwater video was collected along the length of each transect and complemented the diver survey.

Results

Unconsolidated, soft mud (silt-clay; >4 phi) to fine sand (4 to 3 phi) was predominantly found throughout Gloucester Harbor (Figure 5.5A; USGS 1998; NAI 1999; Valente et al. 1999; SAIC 2001; Malkoski personal communication). Surface sediments showed little topography (e.g., ripples), suggesting low seafloor energy that is not subject to substantial sediment transport (SAIC 2001). Seafloor sediments

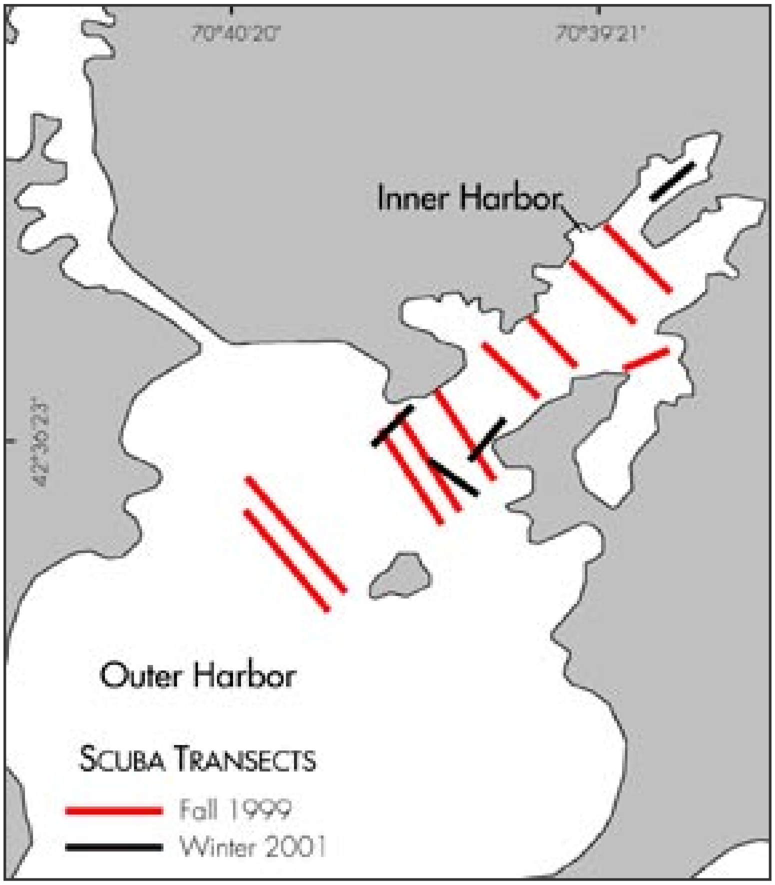

FIGURE 5.4 Location of diving transects in Gloucester Harbor in October 1999 (fall; solid line) and January 2001 (winter; dotted line) (NAI 1999; Malkoski personal communication). Video was collected along the length of each transect.

had relatively low substrate rigidity (i.e., deep camera penetration) and variable RPD depth (Table 5.1; Valente et al. 1999; SAIC 2001).

RPD variance was related to harbor location and grain size. Inner harbor benthos were characterized by soft mud, shallow RPD depth, and sedentary organisms living on the seafloor surface (e.g., epifauna; worms) (Figure 5.6). The navigational channel adjacent to the Paint Factory was a soft mud/fine sand mix and showed comparable camera penetration and RPD depth relative to the outer harbor. Stations around Tenpound Island had unconsolidated soft mud, deep camera penetration, relatively deep RPD, and evidence of infauna feeding at depth (Figure 5.7).

Outer harbor grain size was more variable, with camera penetration and RPD depth associated to grain size. Soft mud sediments in the outer harbor were comparable to samples surrounding Tenpound Island, characterized by deep camera penetration, oxidized surfical sediments (i.e., deep RPD depth), and infauna presence (Figure 5.8). RPD depth was slightly lower in the southeast corner of the outer harbor (i.e., located adjacent to Dog Bar Breakwater). Western outer harbor samples were coarser grained (i.e., medium sand; 3 to 2 phi) and more rigid, limiting the vertical profile of the image and ability to measure RPD depth (Figure 5.9). Samples northeast of Dog Bar Breakwater (near the harbor mouth) were interpreted as hard bottom (consolidated sediment) because of no camera penetration. Western outer harbor is more exposed to Massachusetts Bay and subjected to higher bottom energy and winnowing of fine-grain sediments, resulting in higher sand content and harder bottom.

Areas of coarser-grained sediment (sand) and relatively high surficial relief were observed south and west of Tenpound Island (Figure 5.10; USGS 1998; NAI 1999). The area south of Tenpound Island was generally smooth, soft mud (USGS 1998); local fishermen refer to the area as the “Pancake.” The multibeam survey clearly showed the corridor of the new wastewater outfall, stretching from the old wastewater outfall to south of Dog Bar Breakwater (USGS 1998). Inner harbor and Tenpound Island had relatively smooth, homogeneous mud bottom. Abandoned gear (a.k.a., ghost gear) was extensively found on the seafloor surrounding Tenpound Island and within the inner harbor (NAI 1999). Green crabs, hermit crabs, American lobster, and shellfish species (e.g., blue mussels) were observed throughout the diving survey area (Figure 5.4). Estimates of juvenile and adult lobster relative abundance ranged from 0.06 lobster/m 0.20 lobster/m, indicative of good lobster habitat. The multibeam study area extended well-beyond Gloucester Harbor and showed harder substrate, including coarser-grain sand and cobble,

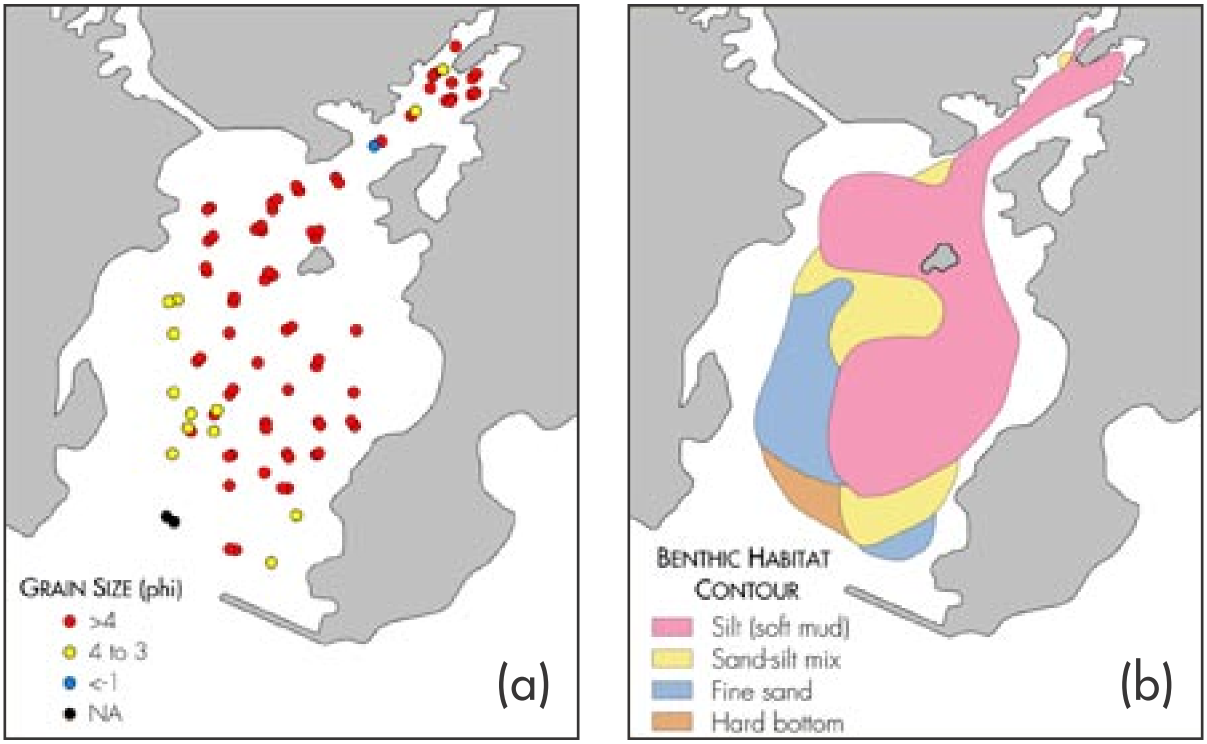

FIGURE 5.5 The 1998 and 2001 sediment profile and surface imaging sample locations, showing (A) major mode grain size from sediment profile imagery; and (B) benthic habitat classification contoured from sediment and surface imagery (Valente et al. 1999; SAIC 2001). Sample station used for hard bottom benthic habitat shown as NA (not analyzed).

outside Dog Bar Breakwater and Eastern Point. Substrate character bordering Eastern Point generally reflects the sedimentary environment of the adjacent shoreline. The diving and multibeam surveys complimented the SPI assessment of seafloor habitat (Figure 5.5b).

Discussion

The inclusion of biotic and abiotic features is essential to identify and describe seafloor habitat. This study presented several surveys, varying in scales and objectives, and the results collectively improved the description of seafloor habitat type and condition in Gloucester Harbor. The multibeam survey predominately showed one sediment type, represented by blue (mud), and provided detailed bathymetry (seamless spatial coverage) throughout the harbor (Figure 5.10). SPI refined the multibeam assessment, finding a range of sediment types from mud to sand (Figure 5.5), and improved the description of habitat quality. Diving supplemented the seafloor description by locating areas of hard bottom and describing biota. Microhabitat features, including small-scale (<1 m) bedforms and biogenic structure, were identified using SPI and diving. The unique contribution of diver surveys was the snapshot evaluation (direct observation) of mobile demersal creatures within the study area. The multibeam, diving, and SPI studies demonstrated the utility of each sampling technique for examining seafloor habitat. A thorough evaluation of habitat quality requires assessments of diverse seafloor resources at varying scales, necessitating the use of multiple techniques.

The sediment profile imaging identified seafloor habitat type and quality. Images presented quantifiable information on sediment features (sediment type, rigidity, and oxic/anoxic conditions) and biological characteristics (presence of benthic epifauna and infauna, burrows, feeding voids, biogenic tubes, and reworked sediments). These characteristics can be associated with the ecological function of the seafloor environment (Nilsson and Rosenberg 1997). Aggregations of polychaetes and no apparent RPD at the seafloor surface are indicative of stressed benthos (e.g., organically enriched and/or recently dis-

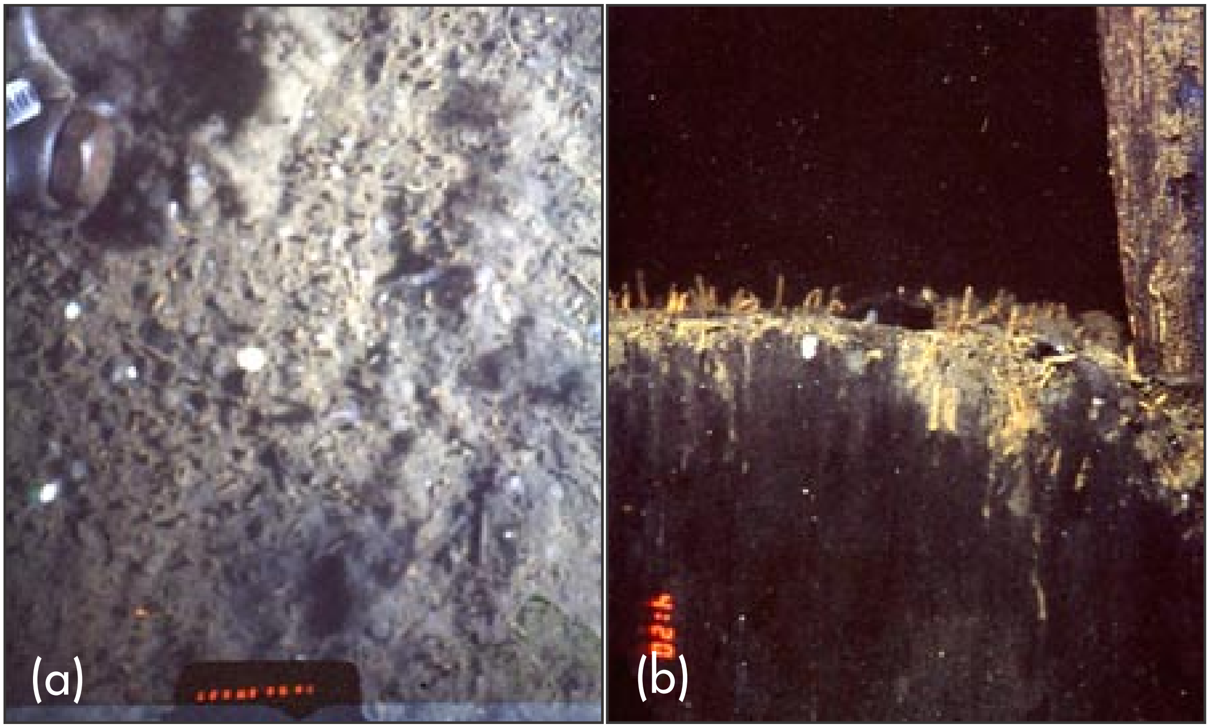

FIGURE 5.6 Representative surface and sediment profile images from the inner harbor. (A) Surface image showing soft mud and worm tubes; (B) Sediment profile image showing soft mud (silt-clay; >4 phi), relatively abundant worm tubes, marine debris (piling), and low apparent surficial sediment oxidation; mean RPD depth is 1.22 cm. Images from Valente et al. 1999.

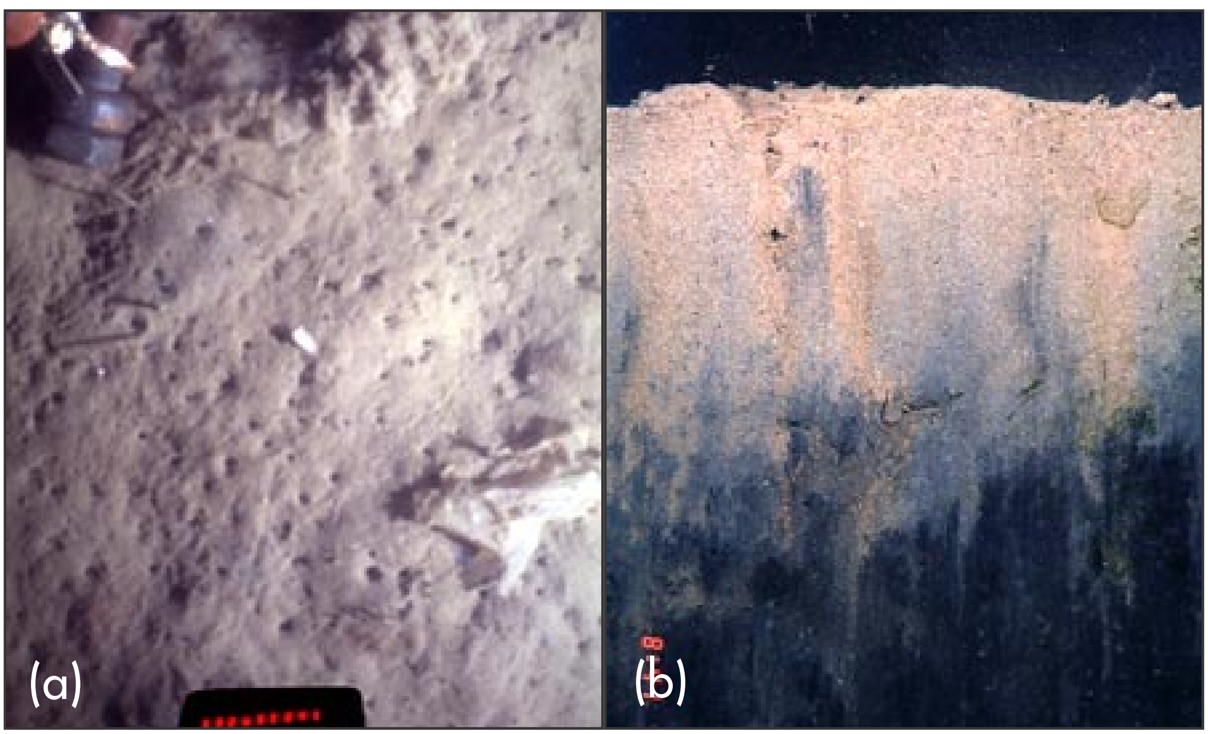

FIGURE 5.7 Representative surface and sediment profile images from benthos adjacent to Tenpound Island. (A) Surface image showing soft mud, abundant burrows, and debris (plastic bag); (B) Sediment profile image showing soft mud (silt-clay; >4 phi), worm tubes, feeding voids, and relatively high surficial sediment oxidation; mean RPD depth is 4.56 cm. Images from Valente et al. 1999.

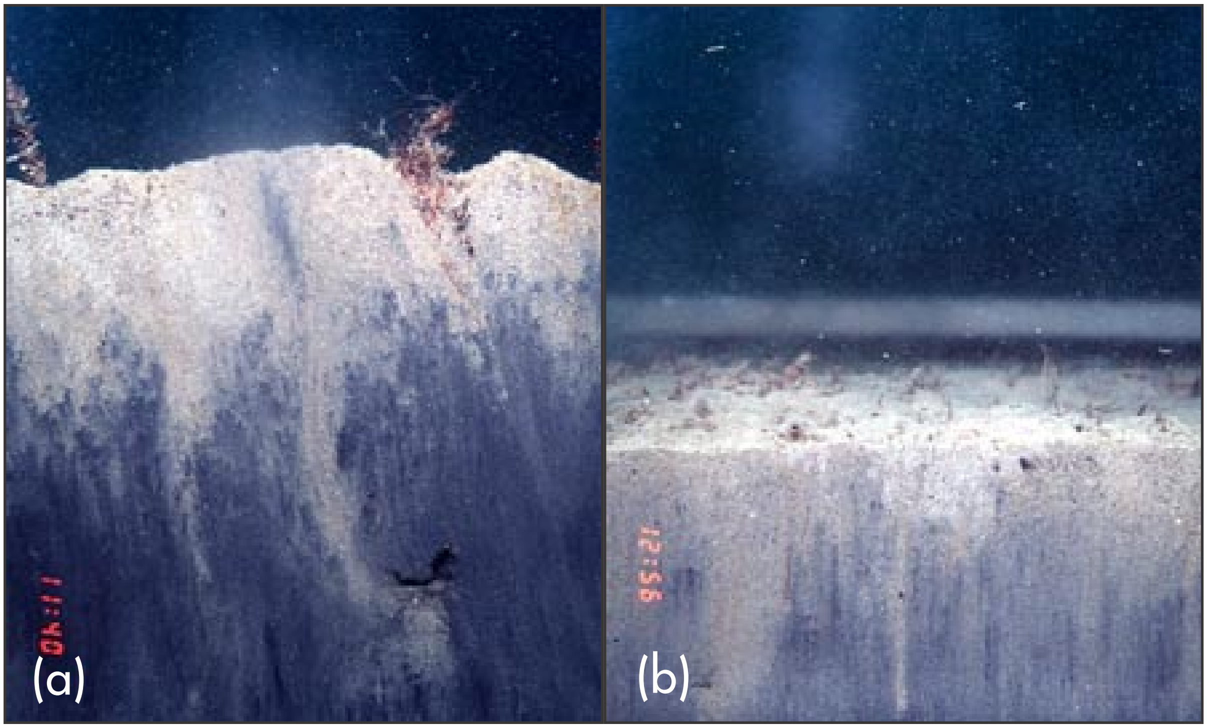

FIGURE 5.8 Representative sediment profile images from soft mud in the outer harbor. (A) Sediment profile image showing soft mud (silt-clay; >4 phi), feeding voids, red algae, relatively high surficial relief, and well-developed apparent sediment oxidation; mean RPD depth is 4.12 cm; (B) Sediment profile image showing soft mud (silt-clay; >4 phi), relatively lower camera penetration, worm tubes, and moderate surficial sediment oxidation; mean RPD is 2.09 cm. Images from SAIC 2001.

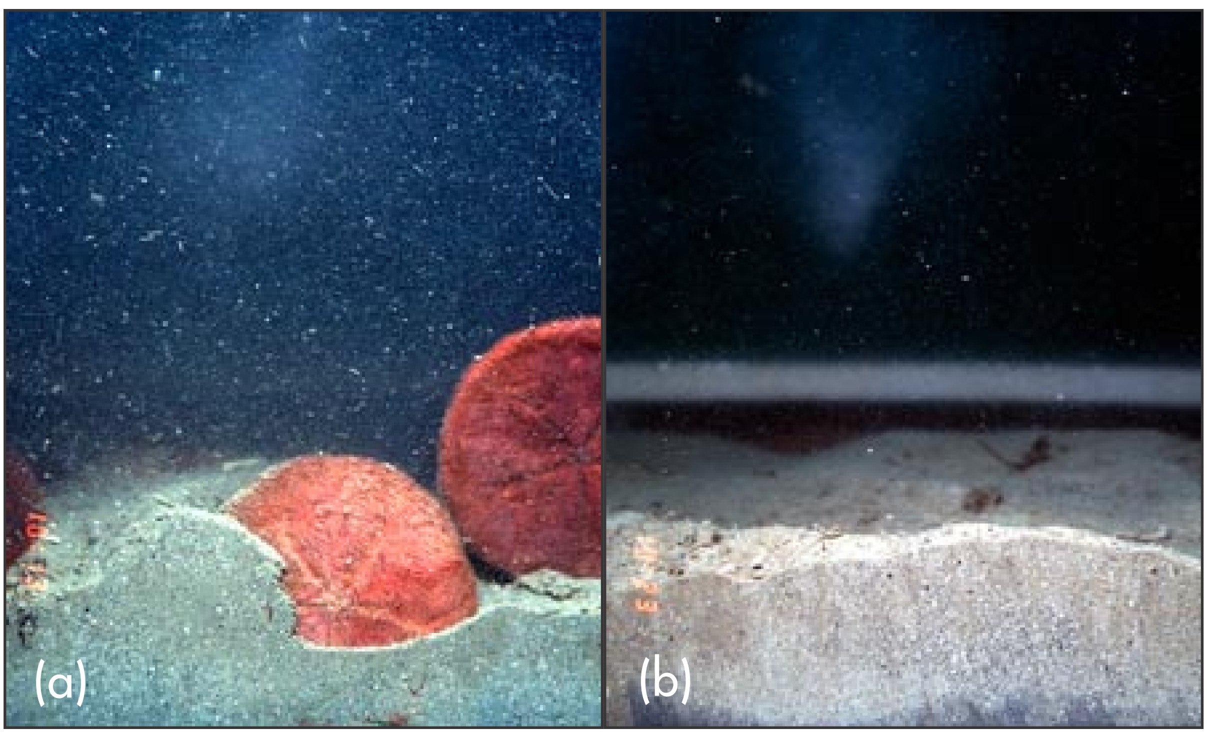

FIGURE 5.9 Representative sediment profile images from sand in the outer harbor. (A) Sediment profile image showing fine sand (4 to 3 phi), sand dollars, low camera penetration, and relatively high surficial relief; (B) Sediment profile image showing fine sand (4 to 3 phi), low camera penetration, and relatively high surficial relief. RPD is not measured because of low camera penetration. Images from SAIC 2001.

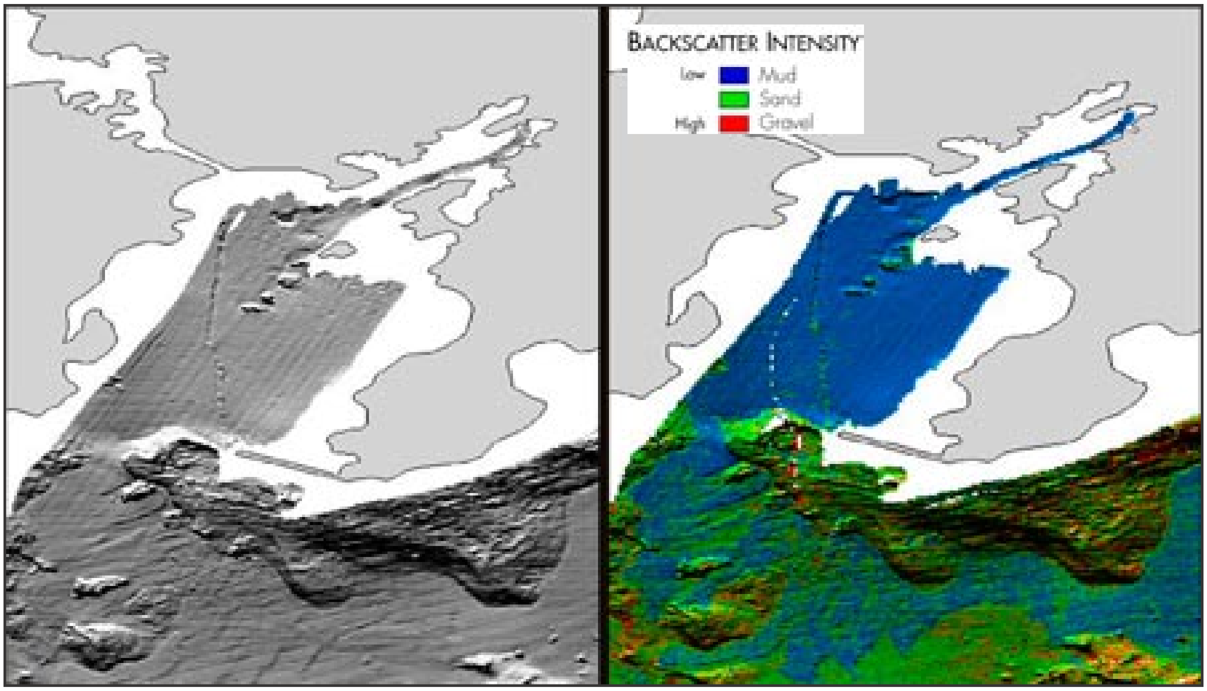

FIGURE 5.10 (A) Sidescan sonar image showing sun-illuminated topography; (B) Sun-illuminated topography with multibeam backscatter intensity for Gloucester Harbor. Red indicates high backscatter material including coarse sand, gravel and rock; green indicates sand; blue indicates mud. The topography is vertically exaggerated to demonstrate small-scale variability (USGS 1998; 2000).

turbed) (Pearson and Rosenberg 1978; Rhoads and Germano 1982, 1986). These features were found in the inner harbor and suggest a high inventory and/or continued input of organic matter. Shallow RPD depths were observed in other nearshore Massachusetts Bay environments (i.e., Boston and Salem Harbor) that are heavily influenced by anthropogenic inputs (Shea et al. 1991; Valente et al. 1999; Arnofsky et al. 2001).

Benthic habitat in the outer portion of the inner harbor, areas adjacent to Tenpound Island, and outer harbor exhibited higher habitat quality and were characterized by well-oxidized seafloor sediments and evidence of infauna (e.g., presence of mollusks or feeding voids). The blackness of sediments underlying the oxygenated sediments at some outer harbor stations indicated a substantial reservoir of organic matter, but the well-developed RPD layer showed benthic organisms may be processing the inputs and maintaining sediment oxidation (SAIC 2001). The relatively lower RPD found behind Dog Bar Breakwater suggested higher rates of organic matter deposition or increased rates of sedimentation relative to erosion—possibly a result of reduced tidal circulation in this area (SAIC 2001).

Stations in the vicinity of the former wastewater outfall were comparable to outer harbor samples. Black, reduced sediment found at one station indicated continued elevated levels of organic matter (SAIC 2001), but prolonged effects from the previous outfall seem spatially limited.

There were notable differences between the 1998 and 2001 SPI surveys in boundary roughness (measure of highest and lowest surficial feature from SPI) and apparent RPD. There was higher boundary roughness and deeper RPD depth in 2001. These features represent higher biological activity and probably reflect seasonal differences (i.e., March 2001 supported higher biological activity compared to November 1998).

The presence of coarse-grained sediment influenced the effectiveness of the SPI technique in areas of the outer harbor because of limited camera penetration. Surface images were not collected in 2001. Surface images enable the characterization of surficial sediment type and biogenic structure, but sub-surface attributes (e.g., oxic/anoxic conditions) are not available. Study areas potentially containing consolidated, coarse-grain sediment should be sampled with surface and sediment profile images to improve habitat description.

Habitat type and quality were described by combining the 1998 and 2001 SPI results, and descriptions were improved using multibeam (USGS 1998) and diving observations (NAI 1999; Malkoski personal communication). Four habitat categories, based primarily on substrate character, were identified in Gloucester Harbor. Sediments were predominantly soft mud and fine sand, transitioning to coarser material toward the western shoreline and mouth of the harbor. Physical, chemical, and biological properties varied among and within habitat types.

The surveys demonstrated a gradient from degraded seafloor habitat quality in the inner harbor to increasingly higher seafloor habitat quality (non-degraded) around Tenpound Island and throughout the outer harbor. Reduced tidal flushing, increased anthropogenic inputs, and physical disturbance apparently influenced seafloor habitat quality in the inner harbor. The reduced habitat quality, however, supported an abundant American lobster population (NAI 1999; Wilbur and Glenn 2002). The inner harbor is closed to commercial lobster fishing, and the lack of fishing effort influences the presence and abundance of lobster. Nevertheless, the presence of lobster suggested that despite the magnitude of degradation in the inner harbor, the system continues to provide habitat to this commercially and ecologically valuable species (Wilbur and Glenn 2002).

Describing habitat requires focused examination of the biological communities, including invertebrate, vertebrate, and plant species, which vary through space and time. Biological sampling to describe the benthic community was not conducted during this study, but benthic infauna were collected at locations in the outer harbor as part of the wastewater outfall monitoring (Michael and Fleming 2000). Monitoring results provided an indication of species presence and relative abundance at a limited spatial scale (Michael and Fleming 2000). Substrate type generally dictates benthic community structure in the Gulf of Maine (e.g., Langton and Uzmann 1989), but small-scale variability in physical structure and topography contributes to variability in biotic assemblages (e.g., Zajac et al. 2000). Habitat categories in this study were primarily founded on substrate type, acknowledging the heterogeneity within habitat classes and along gradients of disturbance. The different methodologies and data collected emphasized the value of individually and mutually using multiple techniques to identify and describe seafloor habitat.

Summary

This study provided a useful overview of existing coastal habitats and eelgrass distribution and presented novel detail on the type and quality of seafloor habitats in Gloucester Harbor. Coastal habitats in Gloucester Harbor were certainly changed through the development of the inner harbor, but outer harbor characteristics remained relatively unaltered. Spatial and temporal trends of eelgrass distribution are unknown. Continued mapping and monitoring of eelgrass in Gloucester (and statewide) increases the understanding of eelgrass and enables resource managers to advance the management of this productive marine habitat. The seafloor habitat studies yielded a tremendous amount of information and should be used, in conjunction with existing coastal and eelgrass maps, for preliminary decision making of coastal activities that potentially affect the marine environment. This synthesis can also be used to design marine monitoring and research intended for examining long-term spatial and temporal trends of seafloor habitat quality.

Gloucester Harbor seafloor habitat quality changed through the development of the economically productive port and alteration of land use in the watershed. Seafloor habitat is not an environmental attribute that is regularly monitored in Massachusetts. Habitat quality, and subsequent ecological function, changes along gradients of human disturbance (e.g., Rhoads and Germano 1986; Valente et al. 1992; Hargrave et al. 1997; Nilsson and Rosenberg 1997). The consequences of seafloor habitat degradation, such as organic loading, oxygen depletion, and physical disturbance, can transfer through trophic levels (e.g., from benthic macrofauna to demersal fishes) (Nilsson and Rosenberg 1997). Seafloor habitat mapping and subsequent systematic monitoring and targeted research are required to detect long-term trends in habitat quality, examine ecological value and function, and determine effects of anthropogenic perturbation. This type of information is necessary to develop effective management strategies to maintain and conserve the integrity of marine habitat and life.

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